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OFFICE OF
PREVENTION, PESTICIDES
AND
TOXIC SUBSTANCES

Memorandum

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SUBJECT: Initial Biological Benefits Assessment for Azinphos-methyl and Phosmet on Almonds

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Summary

Based on available published information and personal communication with crop experts, BEAD believes that extending the restricted entry intervals for phosmet and azinphos-methyl will have little impact on the important use of these chemicals at hull-split. It is expected that growers could adjust their cultural practices to meet the requirements of these extended intervals.

The early-season (May) use of phosmet or azinphos-methyl is not a common practice any longer; however growers with a high population of peach twig borer at this time may apply an insecticide to bring the levels down. Long (> several weeks) restricted entry intervals for the use of azinphos-methyl would practically remove it from the early season use in almond orchards. There are effective alternatives for this use, though there are limitations with each.

Almond growers rely on azinphos-methyl and phosmet later in the season to control two important pests – the navel orangeworm and the peach twig borer. Both pests have the potential to cause significant economic damage to almonds, and have been linked to aflatoxin contamination in the product. Application of the insecticide occurs at hull split in July which takes place approximately four to six weeks prior to harvest. The activities which occur after hull split include harvest, poling of mummy nuts, and pruning. Almonds are not hand harvested. Poling to remove mummy nuts and pruning occurs in winter (November through January), and an extension of the REIs for these activities would be expected to have minimal impact as recommendations for mummy removal from the trees advise that this task should be completed by February.

Background

Nearly all the U.S. commercial production of almonds takes place in California, due to its unique climatic conditions. A rainy, mild winter followed by dry and warm weather in the spring and summer provide ideal conditions for almonds to flourish. However, because of California's climate, irrigation is usually necessary.

Almond trees must be planted in mixed cultivar orchards to allow bees to cross-pollinate, usually in February to early March. Thinning of the blossoms or fruit is not required as pollination naturally limits the set of nuts. Fruit begins to form in mid- to late March, and the nut matures in the July-August time frame. Harvest takes place in August through September and sometimes into early October, depending on the area and the cultivar.

Activities in the orchard take place mostly in the spring and summer, when irrigation, weed management, sampling for nutrient levels, and monitoring for pest and disease problems and for nut maturity are necessary. Applications of phosmet and azinphos-methyl are made at about hull split, in July. Worker activities after these applications include mowing, monitoring of almond maturity for scheduling harvest, orchard floor preparation, and scouting. Preparation of the orchard floor for harvest activities includes discing and rolling to ensure a smooth surface for collecting the fallen nuts, ant control, and removal of debris. These activities require that workers re-enter the fields within two to four days after pesticide application.

Almonds are removed from the tree by mechanical shakers, and allowed to dry for seven to ten days on the clean orchard floor. The almonds are then swept into windrows by mechanical sweepers, the newest of which are similar in appearance to street sweepers and are self-contained, primarily for protection from the dust and heat. Older models are tractor-mounted with open cabs. Blowers are used to move almonds which have fallen at the base of the trees, and these too are swept into windrows and gathered with a mechanical harvester. Hand raking is done in almonds with less and less frequency as labor costs rise. Each orchard is harvested three times over a 4 to 8 week period as different varieties mature.

After harvest, worker activities include poling of the trees to remove mummy nuts (*see* information about alternative control for navel orangeworm), and later in the year, orchard management includes pruning, monitoring for weeds, and application of herbicides and insecticides.

***Production Data for Almonds*:**

<u>U.S. Almonds Production</u>

Commercial production of almonds in the United States is located in California. Total California almond production averaged 703 million pounds from 1997 to 1999, and was valued at $847 million according to the National Agricultural Statistics Service. See Table 1 for additional information.

Table 1. U.S. Almond Production: Area, Production, and Value, 1997 Through 1999 (averages)

U.S./State	Bearing Acreage	Production (million pounds)	Percent of U.S. Production	Value of Production ($1,000)
California	461,000	703	100%	$847,000

Source: USDA/NASS Agricultural Statistics 2000

Pest Biology for Azinphos-methyl and phosmet uses:

Both azinphos-methyl and phosmet are used to control the navel orangeworm and the peach twig borer which are considered major almond pests.

Navel Orangeworm, *Amyloid transitella*. The following is reported in the USDA Crop Profile for Almonds:

Navel orangeworm is the most important pest in almonds. It attacks most soft-shelled cultivars, or nuts with poor seal, feeding inside the nuts on the kernels. The resultant frass and deep channels from feeding render the nut unsalable. Some hard shell cultivars are more resistant to navel orangeworm attack. The navel orangeworm destroys kernels and it is associated with presence of aflatoxins.

Navel orangeworm larvae enter sound nuts after hull split and cause damage before harvest. Navel orangeworm overwinters as larvae inside mummy nuts left on the tree and in trash nuts left on the ground and in tree crotches. Adult moths emerge in spring and lay eggs on mummy nuts or nuts damaged by peach twig borer, which act as a food bridge for this generation of navel orangeworm. After hatching, navel orangeworm larvae of this first generation enter nuts damaged by the peach twig borer. This makes peach twig borer control very important. After hull split adults lay eggs directly on the hull of sound nuts and the tiny larvae enter nuts through the shell seal and do not emerge until they are adults. There are 3 to 4 generations of navel orangeworm per year.

Thirty percent damage to the nut crop is not uncommon in late harvested orchards. Growers are not paid for insect- damaged nuts and are charged sorting costs by processors to remove insect damaged nuts. Navel orangeworm damage is directly correlated to aflatoxin contamination of nuts. The U.S. almond industry is working to reduce their aflatoxin contamination rates because the European Union (EU) implemented stringent aflatoxin standards in 1999. More than 50% of the US almond crop is exported to Western Europe.

Monitoring: Egg traps are used to monitor navel orangeworm and provide proper timing for applying in-season insecticide applications.

Controls

Because of the potential for damage and loss from navel orangeworm, growers typically use several methods to control this pest, as described below.

Cultural Controls

Early harvest and excellent orchard sanitation are probably the most important components for navel orangeworm management in almonds. An early, rapid harvest reduces the opportunity for navel orangeworm larvae to gain access to nuts, reducing the potential for a population increase in the orchard. Because the navel orangeworm larvae overwinter in mummy nuts, the mummies must be removed and destroyed in a timely manner. Because peach twig borers and other lepidopteran damage predisposes nuts to navel orangeworm entry, these pests must be controlled to eliminate food sources for first generation navel orangeworm larvae and preclude an early season buildup of the navel orangeworm population in the orchard. Good sanitation - cleanup of extra nuts - is a must around hullers, bins, dryers, and buildings where nuts have been handled.

The 1987 California document, *Integrated Pest Management for Almonds*, states that “The most effective way to prevent economically destructive populations of navel orangeworm is to remove mummy nuts from the trees in February and destroy them. When a good orchard sanitation program is carried out in an orchard located at least 1/4 mile from infested trees, together with an early harvest, usually no sprays are needed for navel orangeworm damage."

Biological Controls

Two introduced wasps, *Goniozus legneri* and *Pentalitomastix plethoricus,* provide some control of navel orangeworm and are established in many areas but are not effective, by themselves, in controlling the pest.

Bacillus thuringiensis - Multiple sprays can control navel orangeworm, but they are not cost effective. In addition, in cool, wet springs, *Bt* activity against pests is diminished.

Pheromone confusion for navel orangeworm is being researched, but it may be very costly and the reliability of the application puffers needs additional research.

Chemical Control

Chemicals can be an important component for managing navel orangeworm in almonds and their use pre-harvest will provide 50-70 % reduction of the pest if used correctly. In general, grower concerns for moving away from organophosphates such as azinphos-methyl and phosmet include concern for mite outbreaks/predator and honeybee toxicity from use of pyrethroids in-season; secondary pest outbreaks from use of new, narrow-spectrum insecticides such as tebufenozide and spinosad; efficacy and residual control; and the development of resistance.

Azinphos-methyl - 28 days PHI. Applied mid-season to 18.8% of the acres by ground at an average rate of 2 lb. a.i. per acre (1). Azinphos-methyl is the most effective material against navel orangeworm, peach twig borer, and defoliating lepidoptera when applied post-bloom. It is somewhat selective for predaceous mites but is highly toxic to parasitic wasps and generalist predators (5). This is the preferred material because of its longer residual, which makes it useful as navel orangeworm flights at hull split don't occur simultaneously and extends protection for the later harvested nuts. It is less disruptive to natural enemies.

Esfenvalerate and Permethrin - (see peach twig borer). Use of these pyrethroids will reduce navel orangeworm levels if used during growing season, but mite outbreaks are likely, triggering the need for an application of a miticide.

Carbaryl - 0 days PHI. Applied mid-season to 1% of the acreage by ground at an average rate of 3.2 lb. a.i. per acre (1). A useful material because it can be applied in an emergency situation up to 1 day prior to harvest. Effective on navel orangeworm, peach twig borer and other lepidopterous pests. It will also control San Jose scale crawlers and eriophyid mites. However, it is extremely disruptive to natural enemies and will generally cause mite outbreaks. It is toxic to honeybees (5).

Phosmet - (see peach twig borer). Will also reduce navel orangeworm populations. Shorter residual compared to azinphos-methyl.

Chlorpyrifos - Most use is for ants and peach twig borer. Can control navel orangeworm and is a viable alternative to azinphos-methyl.

Diazinon - not registered in-season in California

Malathion - Is not effective against navel orangeworm.

Spinosad - Limited experience with this narrow-spectrum insecticide suggests that the efficacy isn't high.

<u>Peach Twig Borer,</u> *Anarsia lineatella*. The following is reported in the USDA Crop Profile for Almonds.

The peach twig borer is a major pest in almonds, and other stone fruits; damaging almonds by feeding in rapidly growing shoots making it difficult to train young trees. Borers also feed directly on nutmeats causing them to be discarded and creating the greatest economic damage.

Probably of most importance, peach twig borer-damaged nuts contribute to navel orangeworm infestations. Peach twig borer infestations can be overshadowed by the more remarkable damage created by the frass and deep channeling in the nut meat by the navel orangeworm. As with the navel orangeworm, certain cultivars are more susceptible to peach twig borer.

The peach twig borer overwinters as first or second instar larvae in cells, primarily under the thin bark in limb crotches on first-to-third year wood. Overwintered larvae begin emerging at about bud break and feed on young leaves and buds. As terminals elongate, maturing larvae establish themselves in a single shoot or terminal and mine the interior of the shoot causing wilting and death.

Adults begin emerging in April. Moths of this generation generally oviposit on shoots but can infest developing fruit with the potential to cause significant nut loss when populations are heavy. Adults from this next generation emerge in late June or early July with most attacking fruit directly. Larvae feed in hulls or directly on the nutmeats, often causing serious crop loss. Peach twig borer larvae begin entering overwintering sites in August and continue throughout the fall. There are four or more generations each year.

Soft shell almonds are most susceptible to damage from peach twig borer. Before insecticides were available, the California Almond Growers Exchange recorded damage as high as 71%. In soft shell varieties, it is not uncommon to experience greater than 30% nut damage from the peach twig borer in untreated orchards.

Monitoring: Pheromone traps are widely used to monitor peach twig borer phenology and time in-season treatments. The most effective timing is 400 to 500 degree days after the beginning of the flight.

Controls

Biological Controls

Numerous natural enemies attack peach twig borer throughout the egg and larval stage. Natural enemies can cause significant mortality and as less disruptive insecticides are utilized, will probably play a more important role in regulating peach twig borer numbers. Among the most common are the wasps *Paralitomastix varicornis, Hyperteles lividus,* and the grain or itch mite, *Pyemotes ventricosus,* which feed on larvae in the hibernacula. The California gray ant has been found to be a significant predator of the peach twig borer in San Joaquin valley peach orchards.

The primary biological control of peach twig borer relies on the use of *Bacillus thuringiensis*. The program calls for *Bt* treatments at bloom and post-bloom to take advantage of the fact that peach twig borer does a considerable amount of feeding on leaves and stems before boring into new shoots.

Bacillus thuringiensis - 0 days PHI. Applied at least twice per season by ground or air to approximately 25% of the acreage at the average rate of 0.1 lb. a.i. per acre (1). It is selective for lepidoptera. Timing of applications is critical and *Bt* is often not effective when applied in cold, wet springs. Applied at bloom or post-bloom.

Mating disruption has been used for peach twig borer in more high value labor intensive crops such as peaches. Results have been variable and the cost of this program is currently too high for it to be widely adopted in almonds. This may change as better and cheaper formulations of pheromones are developed.

Chemical Controls

Traditionally, the peach twig borer was controlled with a dormant or delayed dormant application of one of the materials listed below. Current practices may include *Bt* at bloom or post-bloom, and in-season application of spinosad, organophosphates or pyrethroids at hull split.

Diazinon - Not labeled for in-season use. Applied to 18.5% of the acres, pre-bloom, at the average rate of 2 lb. a.i. per acre. It is extensively used for ground applications mixed with petroleum oil during the dormant period for control of peach twig borer, San Jose scale, European red and brown almond mite eggs, and fruit tree leafroller eggs. Peach twig borer and San Jose scale resistance has been documented in San Joaquin Valley peach orchards.

Azinphos-methyl - Most effective as an in-season material (see Navel orangeworm).

Esfenvalerate - 21 days PHI. This is a highly effective peach twig borer material when applied by ground during the dormant period. Used on 7% of the acreage by ground at 0.05 lb. a.i. per acre. It is also effective against other lepidopteran pests. This is the most economical material available. The biggest drawback is it disrupts biological control of mites, often even when applied during dormancy.   Esfenvalerate will also control navel orangeworm; however, if used during the growing season this material is very disruptive to the biological control of mites and should only be used during the growing season in an emergency situation. Resistance has developed in some growing areas to esfenvalerate.

Phosmet - 30 days PHI. Effective on navel orangeworm, peach twig borer and other lepidoptera when used during growing season. Also used dormant for peach twig borer. It will control San Jose scale crawlers if crawlers are present. It is applied to 6% of the acres at an average rate of 3.0 lb. a.i. per acre. Phosmet can cause mite outbreaks but is not as disruptive as some other materials.

Carbaryl (see navel orangeworm) - Used late in season when other alternatives cannot be used because of longer PHIs. Disruptive; causes mite outbreaks.

Naled - 4 days PHI. Applied during the dormant period by ground to 1.5 % of the acreage at the rate of 1.5 lb. a.i. per acre. Provides fair control, however resistance develops quickly to naled.

Chlorpyrifos - 14 days PHI. Historically, this material is used as a dormant spray for control of the peach twig borer with over 50 % being used for ant control. For control of peach twig borer it is applied by ground during the dormant period to approximately 10% of the total acreage at an average rate of 1.5 lb. a.i. per acre. Cannot be used during the dormant period in the Sacramento Valley because damage to trees can result. Will also control lepidopteran pests when used post-bloom.

Methidathion - Primary use is for San Jose scale during dormancy. No in-season use.

Permethrin - 7 days PHI. Applied by ground during the dormant period to 10% of the acreage at an average rate of 0.2 lb. a.i. per acre. This is the most economical material available and has low mammalian toxicity. The biggest drawback is it tends to disrupt biological control of mites, even when applied during dormancy. Will also control navel orangeworm if used during the growing season but this material is very disruptive to the biological control of mites and should only be used during the growing season in an emergency situation.

Spinosad - Newly registered. Very effective against peach twig borer. Has been in short supply and is expensive; toxic to honeybees so limited to night application during bloom. No use data are available.

Emamectin benzoate - in pipeline, potential for dormant/in-season use.

Diflubenzuron - in pipeline

Tebufenozide - in pipeline

Economic Effects of Insect Damage:

Approximately 75% of domestic almond production is exported. As a result, the economic viability of the crop for growers is very dependent on criteria for product quality as demanded by the export markets. Following is a discussion of the concerns in the almond industry related to this issue, from Gene Beach, President of the Almond Hullers & Processors Association.

> "The recent change in the EU regulations is forcing U.S. growers to reevaluate the efforts made to prevent insect damage. Currently 2-10% of the product has some insect damage. To meet the EU criteria less than 2% insect damage is needed to have a 95% chance of meeting EU's aflatoxin standards (Schatzki 2001). The economic impact of aflatoxin contamination in the EU market is severe. If a shipped lot tests above the EU limits the costs may be destruction of the shipment or at a minimum the cost of returning the product to the U.S. and losing the sale. However, the almond industry need only look to the experience of the Iranian pistachio industry in Europe to see the economic impact of persistent aflatoxin contamination. Prior to 1997 the Iranians had 95% of the EU pistachio market. In 1997 the EU instituted a 3-month ban on importation of Iranian pistachios due to repeated high findings of aflatoxins. In response the amount of pistachios sold to the EU declined by 50% in 1998 and recovered to 80% in 1999 relative to the volume of pistachios imported in. The total value of the pistachios imported in 1998 declined by 60% and 32% in 1999 relative to the 1996 value. However, 3 years in a row of media reports warning consumers away from the consumption of pistachios in Germany has led to a sustained overall decline in consumption, furthermore Iran has lost market share to other pistachio producing countries. Given the importance of the EU market to the U.S. almond industry and given that Europe is the largest importer of almonds, it is critical that the U.S. industry become more vigilant in preventing aflatoxin contamination and sorting out potentially contaminated nuts. The key to prevention is preventing insect damage in the field and to a lesser extent during storage. Thus maintaining every effective tool against Navel orangeworm and Peach twig borer is critical to maintaining the export market of almonds."

Azinphos-methyl and Phosmet Usage in California

Azinphos-methyl

Table 2 lists the usage of azinphos-methyl on almonds in California. An average of 10% of California almond bearing acreage is treated with azinphos-methyl per year, and about 83,076 pounds of azinphos-methyl are applied. The average number of applications of azinphos-methyl per year in California is 1.05 with an application rate of 1 pound per acre per application. See Table 2 for additional information.

Table 2. Usage of Azinphos-methyl on Almonds in California.

U.S./State	Percent of Crop Treated	Base Acres Treated [1]	Total Pounds Applied (lbs)	Average Number of Applications (#/year)	Average Application Rate (lbs/acre)
California	10%	46,000	83,076	1.05	1.72

Source: Table data is a two year average of California Department of Pesticide Regulation estimates of azinphos- methyl usage from 1998 and 1999.

1. Base acres treated calculated using percent of crop treated estimates against bearing acreage from Table 1.

Note: The US EPA Quantitative Usage Analysis (QUA), 4/99, estimated an average of 21% of the almond crop treated and 160,000 pounds applied in the U.S.; based on ten years of data and multiple data sources.

Phosmet

Table 3 lists the usage of phosmet on almonds in California. An average of 7% of the California almond bearing acreage is treated with phosmet per year, and about 101,000 pounds of phosmet are applied. The average number of applications of phosmet per year in California is 1.12 with an application rate of 2.80 pounds per acre per application. See Table 3 for additional information.

Table 3. Usage of Phosmet on Almonds in California.

U.S./State	Percent of Crop Treated	Base Acres Treated [1]	Total Pounds Applied (lbs)	Average Number of Applications (#/year)	Average Application Rate (lbs/acre)
California	7%	32,200	101,000	1.12	2.80

Source: Table data is a two year average of California Department of Pesticide Regulation estimates of phosmet usage from 1998 and 1999.

1. Base acres treated calculated using percent of crop treated estimates against bearing acreage from Table 1.
Note: The US EPA Quantitative Usage Analysis (QUA), 6/99, estimates an average of 9% crop treated and 87,000 pounds applied in the U.S. Based on ten years of data and multiple data sources.

Usage of Azinphos-methyl and Phosmet by Target Pest

Azinphos-methyl The almond target pests for azinphos-methyl and phosmet are listed in Table 4. All azinphos-methyl usage on almonds is for the control of the navel orangeworm and the peach twig borer. About 65% of the azinphos-methyl applied to almonds is for the control of the navel orangeworm while the remaining 35% is applied to control the peach twig borer.

Phosmet The almond target pests for phosmet are the navel orangeworm, the peach twig borer, and the San Jose scale. Usage of phosmet on almonds is almost identical to usage of azinphos-methyl. Application for control of the navel orangeworm accounts for about 65% of total phosmet usage and application of phosmet for control of the peach twig borer accounts for about 35% of total phosmet usage. Application of phosmet for control of the San Jose scale accounts for a very small share of total phosmet usage on almonds. See Table 4.

Table 4. Target Pests for Azinphos-methyl and Phosmet [1]

Active Ingredient	Target Pest - Listed in Order Importance (Based on Estimated Usage by Pest [2])
Azinphos-methyl	Navel Orangeworm Peach Twig Borer
Phosmet	Navel Orangeworm Peach Twig Borer San Jose Scale

1. Sources: EPA proprietary data.
2. Importance based on the proportion of total azinphos-methyl or phosmet usage (total acre treatments) for the control of the pest.

As stated above, about 65% of both azinphos-methyl and phosmet, respectively, are applied to almonds to control the navel orangeworm. In this pest insecticide market combination azinphos-methyl holds about 15% of the total market and phosmet holds about 10% and the two insecticides rank third and fifth (in terms of total acre treatments), respectively, for this insecticide pest combination. From one to five, the most commonly used insecticides to control the navel orangeworm on almonds are chlorpyrifos, *Bacillus thuringiensis*, azinphos-methyl, permethrin, and phosmet (see Table 5).

Table 5 also lists the percent of the almond crop treated with each active ingredient. For example, according to the USDA's National Agricultural Statistics Service, 17% of the almond crop was treated with chlorpyrifos in 1999. Note that the percent of crop treated number covers all pests, and represents the percent of almond acres treated at least once, regardless of the target pest.

Table 5 does not, however, separate information that is key to understanding the importance of azinphos-methyl and phosmet at hull-split for the navel orangeworm. Because growers' best options for control of navel orangeworm includes several practices, from orchard sanitation to control of the pest at multiple points in the production cycle, one cannot interpret Table 5 to mean that azinphos methyl and phosmet are less important to the grower than other pesticides with more use. These are the insecticides of choice for control of this pest at hull-split.

Table 5. Leading Insecticides used for control of the Navel Orangeworm.

Pest	Insecticide - Listed in Order of Importance (Based on Estimated Usage by Pest [1])	Approximate Share of Total Insecticide Usage to Control the Navel Orangeworm[2]	% Crop Treated (All Pests)
Navel Orange-worm	1. Chlorpyrifos	25%	17%
	2. *Bacillus thuringiensis*	15%	18%
	3. Azinphos-Methyl	**15%**	**10%**
	4. Permethrin	15%	15%
	5. Phosmet	**10%**	**7%**
	6. Esfenvalerate	5%	14%
	7. Spinosad	5%	5%
	8. Propargite[3]	5%	22%
	9. Petroleum Oil	< 5%	58%
	10. Diazinon	< 5%	9%

Source: Target Pest Usage Data is based on EPA proprietary data.

1. Importance based on the proportion of total insecticide usage (total acre treatments) for the control of the navel orangeworm.
2. Source: Phosmet and azinphos-methyl estimates are from Table 2 and 3, respectively. All other estimates are from the USDA/NASS 1999 Fruit and Nut Summary, July 2000.
3. Propargite is a miticide, and is not effective against the navel orangeworm. Usage indicated here is likely related to the use of a pyrethroid to control the target insect, with propargite as follow-up to manage mite outbreaks.

As stated above, about 35% of both azinphos-methyl and phosmet, respectively, are applied to almonds to control the peach twig borer. In this pest insecticide market combination azinphos-methyl holds less than 5% of the total market while phosmet holds approximately 5%. In terms of total acre treatments, among all insecticides used to control the peach twig borer, phosmet ranks number 7 and azinphos-methyl ranks number 10.

Table 6 also lists the percent of the almond crop treated with each active ingredient. For example, according to the National Agricultural Statistics Service, 18% of the almond crop was treated with *Bacillus thuringiensis* in 1999. Note that the percent of crop treated number covers all pests, and represents the percent of almond acres treated at least once, regardless of the target pest.

Table 6 does not separate information that is key to understanding the importance of azinphos-methyl and phosmet at hull-split for the peach twig borer. Growers use many control methods to manage this pest, as for the navel orangeworm. For example, Table 6 suggests that *Bacillus thuringiensis* and esfenvalerate are among the leading insecticides used to control the twig borer. However, *Bacillus thuringiensis* is only used near bloom on smaller worms, taking advantage of their feeding on the shoots; and esfenvalerate is used in the dormant season, when mite outbreaks aren’t facilitated by its toxicity to predators; leaving the window of control at hull-split for azinphos methyl and phosmet.

Table 6. Leading Insecticides used for control of the Peach Twig Borer.

Pest	Insecticide - Listed in Order of Importance (Based on Estimated Usage by Pest)[1]	Approximate Share of Total Insecticide Usage to Control the Peach Twig Borer	% Crop Treated (All Pests)[2]
Peach Twig Borer	1. *Bacillus thuringiensis*	30%	18%
	2. Chlorpyrifos	20%	17%
	3. Esfenvalerate	10%	14%
	4. Permethrin	10%	15%
	5. Petroleum Oil	10%	58%
	6. Diazinon	5%	9%
	7. Phosmet	**5%**	**7%**
	8. Spinosad	5%	5%
	9. Methidathion	< 5%	7%
	10. Azinphos-methyl	**< 5%**	**10%**

Source: Target Pest Usage Data is based on EPA proprietary data.

1. Importance based on the proportion of total insecticide usage (total acre treatments) for the control of the peach twig borer.

2. Source: Phosmet and azinphos-methyl estimates are from Table 2 and 3, respectively. All other estimates are from the USDA/NASS 1999 Fruit and Nut Summary, July 2000.

Impacts associated with proposed mitigation

***REI s for Phosmet and Azinphos-methyl*:**

Phosmet			Azinphos-methyl	
Current label REIs	Registrant proposed REI	PHI	Current label REIs	PHI
24 hours	27 days	14 days	14 days for hand harvesting; 2 or 3 days for all other activities	28 days

Almond growers rely on azinphos-methyl and phosmet to control the important pests navel orangeworm and peach twig borer. Both pests have the potential to cause significant economic damage to almonds, and have been linked to aflatoxin contamination in the product. Application of one of these insecticides occurs at about hull split, approximately four to six weeks prior to harvest. In some cases, an early spray in May to control peach twig borer is needed as well.

Worker activities in the orchard after the application of the pesticides in May include mowing, scouting for pests, irrigation, preparation of the orchard floor for harvest, and monitoring for nut maturity to plan harvest. Growers could accommodate an extended restricted entry interval for these activities after the early season use of phosmet, but a significant extension of the restricted entry interval would effectively cancel an early season use of azinphos-methyl. Please refer to the occupational and residential human health risk assessment on the Agency's website (http://www.epa.gov/pesticides/op) for information concerning the worker risks associated with the restricted entry intervals for this chemical.

Almonds are not hand harvested. Poling to remove mummy nuts occurs in winter (November through January), and an extension of the REIs for the application at hull split for this activity would be expected to have minimal impact as recommendations for mummy removal from the trees advise that this task should be completed by February. Pruning is also done late in the season, and extension of the REI for this task is not expected to conflict with the activity in the orchard.

Sources

Integrated Pest Management for Almonds, 1985. University of California, Statewide Integrated Pest Management Project. Division of Agriculture and Natural Resources. Pub. 3308.

USDA Crop Profile for Almonds in CA. Web address: http://pestdata.ncsu.edu/cropprofiles/docs/caalmonds.html

Update a Pest Management Evaluation for the Almond Industry. Chris Heintz, Almond Board of CA. March 31, 1999. Web address: http://lookercomm.com/almondPMA/Almond%20PME/1999pme.html

The Foundation for a Pest Management Strategic Plan in Almond Production. Almond Board of CA. June 12, 2000. Web Address: http://pestdata.ncsu.edu/pmsp/index.cfm

Crop Profile for Almonds in California

General Production Information

- In North America, California is the only state that commercially produces almonds. Over the last 5 years California has produced, on average, 67.4% of the world=s almonds; ranging as high as 74.8% in 1996 (10).
- The California almond industry has 6,000 growers farming about 470,000 acres. Average annual production between 1992 and 1997 in California was 528,220,000 pounds (10).
- Average annual crop value during those years amounted to $895,326,000. In 1997 the value of the crop exceeded $1,008,500,000 (10).
- Between 72% and 79% of the crop has been exported during the last 4 years (10).
- The average total cost to produce an acre of almonds amounts to $2,767 (18, 19).

Production Regions

Over 99% of the almonds in California are produced in the San Joaquin and Sacramento Valleys. Approximately 80% of the production is in the San Joaquin Valley. Kern and Fresno Counties in the south and Merced and Stanislaus in the north are the highest producing counties in the San Joaquin Valley (15). Glenn, Butte, and Colusa Counties in the Northern Sacramento Valley account for approximately 15% of the annual production in the state with the remainder being grown in the southern part of the Sacramento Valley (15). Other regions of the state account for <1% of the almond production.

Cultural Practices

Approximately 50 varieties of almonds are grown commercially in the state with Nonpareil accounting for about 40-45% of the production. Other important varieties grown in California include Carmel, Mission, Price, Butte, Neplus, Fritz, and Monterey (14). The vast majority of major commercial cultivars of almond in California are self-unfruitful and cross-pollinated by insects, primarily honeybees (6). Honeybees in overwintered colonies are the only pollinators currently available in adequate numbers to service the almond industry in California. Planting patterns vary, but generally in newer plantings, the main variety is planted in alternate rows with a pollinizer that overlaps the main variety at time of bloom (6).

Selected varieties are grafted onto rootstocks. Rootstock selection is based on cultivar compatibility, soil texture and drainage, pests (primarily nematodes) and weather conditions of the orchard site. Although several rootstocks are available, the 2 main rootstocks used are Nemaguard and Lovell peach (6). Other less common rootstocks include Nemared, Marianna 2624 plum, various peach and almond hybrids and almond itself (6). Both varieties and rootstocks vary in susceptibility to diseases, nematodes and insect pests.

Almonds are most productive on loam-textured, deep uniform soils. However, many orchards are planted in less than ideal sites but produce economical crops with soil modification and proper care. Irrigation is essential for the economic production of almonds in all parts of the state. Flood, furrow, and sprinkler irrigation are predominant with drip and micro-sprinkler irrigation being used more often, especially in marginal soils (6).

Non-cultivation of orchard soils with herbicide-treated strips down tree rows is common. Orchard floor management is of particular importance to an almond grower because the crop is picked up off the soil surface after being knocked from the trees and swept into windrows. Whether an orchard is tilled, non-tilled, herbicide-treated, or cover-cropped, a primary consideration when performing any cultural operation during the year must be to ensure that the orchard floor is the best possible condition for harvesting (6).

Almonds begin blooming in mid-February before the danger of frost has passed. Bare ground absorbs more heat and can reduce the threat of frost damage. Early season frost protection by close mowing or herbicide treatment is also an important consideration in orchard floor management (5).

Insect Pests

A variety of insect and mite pests attack almonds in California. These pests are present in all almond-growing areas of the state and occur at damaging levels most seasons. The distribution and damage potential of others are more restricted.

Major Insect Pests

Navel Orangeworm, *Amyelois transitella*:
Navel Orangeworm (NOW) is the most important insect pest in almonds (2). NOW attacks most soft-shell cultivars, or nuts with poor seal, feeding inside the nuts on the kernels. Some hard shell cultivars are more or less resistant to attack by NOW. It not only destroys kernels but is associated with fungi responsible for aflatoxins, (2). Navel orangeworm larvae cannot enter sound nuts before hullsplit so damage occurs after hullsplit and before harvest. Navel orangeworm overwinters as larvae inside mummy nuts left on the tree and in trash nuts left on the ground and in tree crotches. Silver gray moths of the overwintered brood emerge in spring and lay eggs on mummy nuts or nuts damaged by peach twig borer, which act as a food bridge for this generation. After hatching, white neonate larvae of the first generation again enter nuts damaged by peach twig borer (2). This makes peach twig borer control extremely important. Larvae mature inside nuts producing large amounts of frass and webbing. Mature larvae are white or pinkish and may reach 5/8 inches in length. After hullsplit adults lay eggs directly on the hull of sound nuts and the tiny larvae enter nuts through the shell seal and do not emerge until they are adults (5). There are 3 to 4 generations per year. Thirty-% damage is not uncommon in late harvested orchards, (16). **Monitoring:** Egg traps are used to monitor NOW and provide proper timing for applying in-season insecticide applications.

Controls

No single control tactic, used alone, will control navel orangeworm. In order to manage navel orangeworm effectively, orchard sanitation, early harvest, on-farm fumigation, and chemical control are needed for reliable management (2).

Biological
Two introduced wasps, *Goniozus legneri* and *Pentalitomastix plethoricus,* are established in many areas but are not effective, by themselves, in controlling NOW (5).

Bacillus thuringiensis B Multiple sprays can control NOW, but they are not cost effective.

Cultural
Peach twig borer and other lepidopterous pests must be controlled to eliminate sources for 1st generation larvae and preclude an early buildup inside the orchard (2).

Mummy nuts are shaken or knocked from trees and destroyed to reduce overwintering populations. In addition good sanitation is a must around hullers, bins, dryers, and buildings where nuts have been handled (2).

Early and rapid harvest to remove the nuts from the orchard to prevent egg laying and infestation is important (2).

Chemical
Pre-harvest chemicals can be an important component of the 4-step program for managing navel

orangeworm in almonds and will provide 50-70 % reduction if used correctly (2).

Fumigation
On-farm fumigation to kill eggs and neonate larvae before nuts can become infested is an important part of the navel orangeworm control package.

- **Aluminum Phosphide** B Labeled at the rate of 100B200 pellets or 20-40 tablets per 1000 cubic feet. Applied to harvested nuts from 11.6% of the acres at an average rate of 0.02 lb. a.i. (1) Applied under tarps prior to hulling and processing.

- **Azinphos-methyl -** 28 days PHI. Applied mid-season to 18.8% of the acres by ground at an average rate of 2 lb. a.i. per acre (1). Azinphos-methyl is the most effective material against navel orangeworm, peach twig borer, and defoliating lepidoptera when applied post-bloom. It is somewhat selective for predaceous mites but highly toxic to parasitic wasps and generalist predators (5). This is the preferred material because of its longer residual. It is less disruptive to natural enemies and has some fuming action.

- **Esfenvalerate** B (see peach twig borer). Will reduce navel orangeworm if used during growing season. Will cause mite outbreaks.

- **Permethrin** B (see peach twig borer). Effective against navel orangeworm if used during growing season. Usefulness of this material is limited due to severe mite flare-ups following its use during the growing season (5).

- **Carbaryl -** 0 days PHI. Applied mid-season to 1% of the acreage by ground at an average rate of 3.2 lb. a.i. per acre (1). A useful material because it can be applied in an emergency situation up to 1 day prior to harvest. Effective on navel orangeworm, peach twig borer and other lepidopterous pests. It will also control San Jose scale crawlers and eriophyid mites. Extremely disruptive to natural enemies and will generally cause mite outbreaks. It is toxic to honeybees (5).

- **Phosmet -** (see peach twig borer). Will also reduce navel orangeworm.

- **Chlorpyrifos** B Most use is for ants and peach twig borer. Can control NOW and is a viable alternative to azinphos-methyl.

- **Methidathion** B Not used for NOW.

- **Diazinon** B Is not registered for in-season use in California, therefore not used to control NOW.

- **Malathion** B Is not effective against NOW.

Peach Twig Borer, *Anarsia lineatella*:
Peach twig borer (PTB) is a major pest in almonds and other stone fruits. PTB damages almonds by feeding in rapidly growing shoots making it difficult to train young trees. However direct feeding on nutmeats causing them to be discarded creating the greatest economic damage. PTB damaged nuts also contribute to navel orangeworm problems. Prior to the movement of navel orangeworm into California the PTB was the most important worm pest of almond (6). In the absence of adequate control measures, the potential for extensive loss to PTB still exists.

Adult PTB are 8-11 mm long with steel gray mottled forewings. Eggs are yellow-white to orange and bluntly oval with surface reticulations. They are laid on fruit surfaces, on twig terminals or on the undersides of leaves. Larvae are brown with distinctive alternating dark and light bands around the abdomen. In almonds the brown pupae may be found between the hull and shell of dried nuts and other places on the trees (5).

PTB overwinters as first or second instar larvae in cells, primarily under the thin bark in limb crotches on first-to-third year wood. Overwintered larvae begin emerging at about bud break and feed on young leaves and buds. As terminals elongate, maturing larvae establish themselves in a single shoot or terminal and mine the interior of the shoot causing wilting and death of the shoot. Overwintered generation adults usually begin emerging in April. Moths of this generation generally oviposit on shoots but can infest developing fruit causing serious nut loss when populations are heavy. Adults from this generation emerge in Late June or early July with most attacking fruit directly. Larvae feed in hulls or directly on the meats, often causing serious crop loss. Peach twig borer larvae begin entering overwintering sites in August and continue throughout the fall. There are 4 or more generations each year (2).

Soft-shell almonds are most susceptible to damage from PTB. Before insecticides were available, the California Almond Growers Exchange recorded damage as high as 71% (6). In soft shell varieties, it is not uncommon to experience >30% nut damage in untreated orchards. **Monitoring:** Pheromone traps are widely used to monitor PTB phenology and time in-season treatments. The most effective timing is 400 to 500 degree days after the beginning of the flight (5).

Controls

Biological
Numerous natural enemies attack PTB throughout the egg and larval stage. Among the most common are *Paralitomastix varicornis, Hyperteles lividus,* and the grain or itch mite, *Pyemotes ventricosus,* which feed on larvae in the hibernacula. The California gray ant has been found to be a significant predator of PTB in San Joaquin valley peach orchards. Natural enemies can cause significant mortality and as less disruptive insecticides are utilized will probably play a more important role in regulating PTB numbers (2, 5)

The primary biological control of peach twig borer relies on the use of *Bacillus thuringiensis*. The program calls for Bt treatments at the beginning and late bloom to take advantage of the fact that PTB does a considerable amount of feeding on leaves and stems before boring into new shoots (5).

***Bacillus thuringiensis* -** 0 days PHI. Applied at least twice per season by ground or air to approximately 25% of the acreage at the average rate of 0.1 lb. a.i. per acre (1). It has low mammalian toxicity, is selective for lepidoptera and is not harmful to wildlife or aquatic organisms. Timing of applications is critical and is often not effective during cold, wet springs. Applied at bloom or post-bloom.

Mating disruption has been used for PTB in more high value labor intensive crops such as peaches. Results have been variable and the cost of this program is currently too high for it to be widely adopted in almonds. This may change as better and cheaper formulations are developed.

Chemical
Traditionally, PTB was controlled with a dormant or delayed dormant application of one of the materials listed below. Current practices may include Bt at bloom or post-bloom, and in-season application of spinosad, or organophosphates or pyrethroids at hullsplit.

- **Diazinon** B Not labeled for in-season use. Applied to 18.5% of the acres, pre-bloom, at the average rate of 2 lb. a.i. per acre (1). It is extensively used for ground applications mixed with petroleum oil during dormant period for control of PTB, San Jose scale, European red and brown almond mite eggs, and fruittree leafroller eggs. Peach twig borer and San Jose scale resistance has been documented in San Joaquin Valley peach orchards.

- **Azinphos-methyl** B Most effective as an in-season material. (see Navel orangeworm)

- **Esfenvalerate** B 21 days PHI. This is a highly effective peach twig borer material when applied by ground during the dormant period. Used on 7% of the acreage by ground at 0.05 lb. a.i. per acre (1). It is also effective against other lepidopterous pests. This is the most economical material available and has low mammalian toxicity. The biggest drawback is it disrupts biological control of mites, often even when applied during dormancy (5). Esfenvalerate will also control navel orangeworm,(5), if used during the growing season but this material is very disruptive to the biological control of mites and should only be used during the growing season in an emergency situation. Resistance has developed in some growing areas to esfenvalerate.

- **Phosmet** B 30 days PHI. Effective on navel orangeworm, peach twig borer and other lepidoptera when used during growing season. Also used dormant for peach twig borer. It will control San Jose scale crawlers if crawlers are present. It is applied to 6% of the acres at an average rate of 3.0 lb. a.i. per acre (1). Phosmet can cause mite outbreaks but is not as disruptive as some other materials.

- **Carbaryl** (see navel orangeworm) B Used late in season when other alternatives cannot be used because of longer PHIs.

- **Naled -** 4 days PHI. Applied during the dormant period by ground to 1.5 % of the acreage at the rate of 1.5 lb. a.i. per acre, (1). Provides fair control, however resistance develops quickly to naled (16).

- **Chlorpyrifos -** 14 days PHI. Historically, this material is used as a dormant spray for control of PTB with over 50 % being used for ant control. For control of PTB it is applied by ground during the dormant period to approximately 10% of the total acreage at an average rate of 1.5 lb. a.i. per acre (1). Cannot be used during the dormant period in the Sacramento Valley because damage to trees can result (5). Will also control lepidopterous pests when used post-bloom.

- **Methidathion -** Primary use is for San Jose scale. No in-season use.

- **Permethrin** B 7 days PHI. Applied by ground during the dormant period to 10% of the acreage at an average rate of 0.2 lb. a.i. per acre (1). This is the most economical material available and has low mammalian toxicity. The biggest drawback is it tends to disrupt biological control of mites, even when applied during dormancy. Will also control navel orangeworm if used during the growing season but this material is very disruptive to the biological control of mites (5) and should only be used during the growing season in an emergency situation.

- **Spinosad** B Newly registered. Very effective against PTB. Has been in short supply and is expensive (16). No use data are available.

Ants

Pavement Ant,*Tetramerium caespitum*
Southern Fire Ant,*Solenopsis xyloni*:
Ants are significant pests of almond, particularly in central and southern areas of the San Joaquin Valley. As the use of drip irrigation and mini-sprinklers increase, ants will probably increase in importance in other areas (16). The pavement ant is 0.13 inches long, brown and covered with coarse hairs. It prefers to nest in sandy or loam soils. The southern fire ant is 0.1 to 0.25 inches long, has an amber head and thorax with a black abdomen. Ants are principally a problem after almonds are on the ground and damage increases in relation to the length of time they remain on the ground before being picked up. Ants can completely hollow out nutmeats leaving only the pellicle (2, 5). Damage is also lower on varieties with good shell seals but can exceed 20% in susceptible cultivars. **Monitoring:** Potential ant damage can be estimated by counting the number of colonies in 5000 sq. feet (5).

Controls

Cultural
Removing nuts from the orchard floor as rapidly as possible after shaking can minimize ant damage.

Chemical

- **Chlorpyrifos** B 14 days PHI. This is currently the most effective registered material for control of ants. Applied to the orchard floor at the rate of 2 lb. a.i. per acre with approximately 10% of the acreage being treated in this manner (1). When ant colonies are concentrated on berms 6-10 ft. band treatments are effective.

- **Permethrin** B (See peach twig borer). Not very effective. Quick knock down, but no residual activity.

Mites

Two-spotted Mite, *Tetranychus urticae*
Pacific Mite, *Tetranychus pacificus*
European Red Mite, *Panonychus ulmi*
Brown Almond Mite, *Bryobia rubioculus*:
Although European red mite can build up to high numbers, they seldom reach damaging populations. However, both two-spotted and Pacific mites can cause almost complete defoliation that exposes trees and fruit to sunburn, reduces fruit size and sugar, and can interfere with harvest (2). Pacific mite is the dominant species in the San Joaquin Valley and two-spotted mite predominates in the Sacramento Valley. However, over the years Pacific mite has become more common in the Sacramento Valley, possibly due to the use of propargite which is more effective on two-spotted mite. Pacific and two-spotted mites over-winter as adult females in the trees or on the orchard floor. Both species are favored by hot, dry conditions and as the weather becomes warmer, they increase in numbers and move throughout the tree (2). Severe defoliation early in the season can cause a 25% reduction in yield the following year (16). As the season progresses, the potential for direct damage decreases. **Monitoring:** Mites can be monitored by leaf brushing or presence/absence sampling (5).

Controls

Biological Control
Predators are important in regulating mite populations. The most dependable predator is the Western Orchard predator mite, *Galandromus occidentalis,* which, if not disturbed by some pesticides applied for other pests, can usually keep populations below damaging levels in well managed orchards. *G. occidentalis* is resistant to most organophosphates and insect growth regulators used for navel

orangeworm and PTB control but extremely susceptible to synthetic pyrethroids and carbamates (5). It should be noted that the predatory mites bred and released by Dr. Marjory Hoy at UCB were resistant to organophosphates, carbaryl, and sulfur. It is not known if most of the predators found today still retain those characteristics. Other important predators include six-spotted thrips, minute pirate bug and a small beetle, the spider mite destroyer.

Cultural
Minimize dust on orchard roads and maintain a well managed ground cover. Well irrigated, vigorous trees are less susceptible to mite damage (2).

Chemical

- **Propargite -** 21 days PHI. Applied post-bloom by ground to 27% of the acres at the rate of 1.5 lb. a.i. per acre (1). Propargite fits well in an IPM program and is the most effective material available. Does not disrupt biological control of mites.

- **Fenbutatin-oxide -** 14 days PHI. Applied post-bloom by ground to 10% of the acres at the rate of 0.5 lb. a.i. per acre (1). Does not disrupt biological control of mites and aphids. Fits well in an IPM program. Does not work well in cool weather.

- **Clofentezine -** 30 days PHI. Applied post-bloom as a preventative treatment by ground to 6% of the acres at the rate of 0.1 lb. a.i. per acre as a preventative treatment (1). Does not control high mite populations. Does not disrupt biological control of mites is not a problem in almonds. Fits well in an IPM program.

- **Narrow Range Oils. -** 0 days PHI. Use data not available. Can be applied post-bloom by ground at the rate of 4 gallons per acre (16). This is a selective material. Effective acaricides when mite populations are low and predators are present. Oils must be used with caution because of potential phytotoxicity if trees are stressed or dry (5). Oils fit well in the IPM program if predator mites are present. **Oil, when used alone does not control peach twig borer.** A drawback with oils is they contribute to air pollution because of hydrocarbon volatilization.

- **Abamectin** B Must be used early season when trees are actively growing. No use data available.

- **Pyramite** B New material. Too early to determine effectiveness. No use data available.

San Jose Scale, *Quadraspidiotus perniciosus*:
Armored scales suck plant juices from the inner bark by inserting their mouthparts into twigs and branches. Infested branches stop growing and heavily infested branches and fruit spurs will die. San Jose scale can kill scaffolds. A small, gray shell that makes control difficult covers San Jose scale. If the shell

covering is removed the small yellow body can be seen (2). Newly hatched nymphs move from under the shell and settle on branches and twigs. The best time to control scale is during the dormant period or in early season after hatching until the covering is well developed. San Jose scale has 3-5 generations per year. Heavy populations may reduce production by as much as 10% if left uncontrolled. **Monitoring:** Look for the presence of scales on twigs and branches (2) and check fruiting spurs. Scale pheromone traps and sticky traps are useful monitoring tools for timing decisions only.

Controls

Biological
Several natural enemies tend to hold armored scale populations in check. Two predaceous beetles, the twice-stabbed ladybird beetle, *Chilocorus orbus* and *Cybocephalus californicus* often occur in large numbers and can keep low to moderate populations in check. Two parasitic wasps, an *Aphytus sp.* and *Prospaltella sp.,* also help as a barrier to population increase. However once populations are high, these natural enemies may not respond fast enough to prevent damage and sprays are needed (2).

Cultural
Prevent dust, which interferes with parasites.

Chemical

Because armored scales spend most of their life protected beneath the scale covering correct timing and spray coverage is important.

- **Methidathion -** 80 days PHI. The most effective material for armored scales. Applied primarily dormant to 10.5% of the acres at the rate of 2.0 lb. a.i. per acre (1). Will help control peach twig borer (5). Disruptive to biological control of mites if used during the growing season.

- **Dormant Oils** B 0 days PHI. Applied during dormant to 40% of the acreage at the average rate of 3.5 gallons per acre (1). Will also control overwintering mite eggs.

Minor or Occasional Insect Pests Controlled With Current Materials

Eriophyid Mites

Peach Silver Mite, *Aculus cornutus*:
Although large numbers of eriophyids may be present, they are seldom considered pests. In low and moderate numbers they are considered beneficial because they act as early season prey for mite predators. Extremely high peach silver mite populations on almond leaves can cause leaves to turn yellow, scorch and drop. Silver mite problems can be aggravated by the use of synthetic pyrethroids (4).

Controls

Biological
Predaceous mites are important in managing eriophyid mite populations and are capable of regulating populations at a low level in undisturbed situations. The key to biological control of these species is to avoid disruptive chemicals, especially synthetic pyrethroids, which enhance population explosions (16).

Chemical
No treatment thresholds have been established but several hundred per leaf can be tolerated.

If treatments are needed, sulfur sprays are a viable option for control of these species and is the material of choice in an IPM program. All of the acaricides will control these species.

- **Sulfur -** Applied to 9% of the acreage at the average rate of 4.5 lb. a.i. per acre (1). Preferred material for eriophyid mites. Will also control almond rust and scab.

Lepidopterous Wood Boring Insects

Peachtree Borer, *Synanthedon exitosa*
American Plum Borer, *Euzophera semifuneralis*:

Both species attack the trunk of healthy trees, boring into the trunk and mining in the cambium layer. Feeding by both species can weaken trees. Feeding by the American plum borer has been observed to cause scaffold limbs on two year old trees to break (5). Treatment for American plum borers is rarely made. Peachtree borers are not a significant enough problem to warrant treatment. **Monitoring:** Pheromone traps are available for monitoring peachtree borer (8).

Controls

Cultural
Cut out infested areas with knife. This is not practical on a commercial scale since infestations are often hard to see and damage caused by removing infected areas can girdle the tree if too extensive.

Mating disruption is available for high value crops but it is not economically feasible in almonds.

Chemical
Spot spraying with hand sprayers is effective for both species. Treating infested areas with a mixture of latex paint and carbaryl can control American plum borer.

Leaffooted Bug, *Leptoglosssus clypealis*:
The leaffooted bug is an infrequent pest in almonds but can cause severe damage in certain areas and to certain varieties. Adults are about 20 mm long, yellowish brown, and have a yellow band across the middle of its back. The back is flat, and the hind legs have characteristic leaf-like enlargements. The leaffooted bug overwinters near orchards often in conifers such as juniper, and arborvitae, and around prop piles or other protected areas. It feeds on young nuts before the shell hardens, causing the embryo to wither and abort, or it may cause the nut to gum internally, resulting in a bump or gumming on the shell. After shell hardening, leaffooted bug feeding can cause black spot or wrinkled, misshapen kernels. Leaffooted bug feeding can also cause nuts to drop (2).

Controls

Chemical

- **Carbaryl -** (see navel orangeworm). The only material recommended for control of this pest although other materials, such as synthetic pyrethroids are effective.

Leafrollers

Oblique-banded Leafroller, *Choristoneura rosaceana*:
Larvae feed on leaves, buds and fruit, but rarely cause enough damage to warrant treating. Oblique-banded leafroller (OBLR) has two or possibly three generations each year. It overwinters mostly as third instar larvae within closely spun cocoons on host trees. As foliage emerges, larvae often tie terminal leaves together for shelter. Adults are tan with alternating light and dark brown bands across their forewings. Eggs are greenish yellow, flattened and laid in overlapping masses. Larvae are green in color often exceeding 30 mm in length at maturity (5). Damage from the summer generation is most serious as almost mature larvae consume nut hulls prior to hull split causing nuts to shrivel and mold and allow

NOW to enter at points where hulls have been chewed (16). **Monitoring:** Pheromone traps are available for monitoring OBLR but are of little practical value except to detect presence in the orchard and when to expect second generation OBLR larvae (16).

Controls

Biological
Several parasitic wasps are important in regulating OBLR populations including *Macracentrus iridescens* and *Pteromalus spp*. In addition, hemipterian predators, *Brochymena sulcatus* and several *Phytocoris spp*. have been observed feeding on eggs and larvae (5).

Mating disruption is under development in pome fruits but has not been perfected for leafrollers.

Chemical
Dormant organophosphate treatments applied for PTB, San Jose Scale and other pests generally control leafrollers in almonds.

Oriental Fruit Moth,*Grapholita molesta*:
Before the late 1980s, Oriental Fruit Moth (OFM) was not considered a significant pest of almond, although large numbers of moths were routinely trapped in almond orchards. Since the mid-1980s, OFM has been reported as an occasional pest especially in the central San Joaquin Valley (7). Adults are small gray moths 6 to 10 mm long. Eggs are creamy white, slightly convex discs and are usually laid on the underside of leaves near the end of terminals. Larvae are white when small but turn pinkish during the last instar. Mature larvae are 10-15 mm long. OFM over-winter as pre-pupae and emerge as adults in late February or early March. There are 5 generations per year. Early in the year larvae feed in shoots causing them to wilt and die. Later, after hullsplit larvae generally feed between the hull and shell but for some unknown reason occasionally bore through the shell and feed on meats, causing damage similar to PTB. Much of the time, unless a larva is found, the damage would be classified as PTB damage (16). Certain varieties seem to be more prone to damage by OFM. Damage as high as 10% of the nutmeats has been documented in Merced County (7). **Monitoring:** OFM is monitored with pheromone traps. When treatment is necessary, applications are made utilizing day degrees.

Woodboring Beetles

Shothole Borer, *Scolytus rugulosus*
Branch and Twig Borer, *Polycaon confertus*
Pacific Flatheaded Borer, *Chrysobothris mali*:
Woodboring beetles generally limit their attacks in almonds to sunburned, unhealthy trees and can be managed by encouraging healthy trees through proper nutrition and irrigation practices. Infested trees and scaffolds can be removed and destroyed to kill beetles inside (2).

Controls

Cultural
Flatheaded borer in newly planted trees can be prevented by properly painting the trunk with white latex paint or using trunk wraps to prevent sunburn (5).

Shothole beetles are managed by keeping trees healthy and removing and destroying infested trees.

Diseases

Almonds are subject to numerous diseases that reduce yield and quality of the crop and sometimes weaken and kill trees. For many of the more serious diseases, the only management tools available are preventative treatments that protect flowers, leaves and fruit prior to infection (9).

Brown Rot, *Monilinia laxa or Monilinia fructicola*:
Brown rot can be a serious problem on almond and other stone fruits such as cherry, peach and apricot. Butte, NePlus Ultra, Carmel, Thompson, and Mission cultivars are often severely blighted, whereas Nonpareil, Price, and Fritz usually sustain less damage (6). The disease occurs in most almond producing areas in California and is worse when rains or fog occur during bloom. The fungus overwinters in twig cankers or in dead blossom parts. In early spring the fungus produces sporodochia where spores are produced. Spores are wind-disseminated to blossoms. Infected flowers wither, collapse, and remain attached to the fruit spurs. The fungus grows from the blossom into fruiting spurs or twigs to form cankers. The nearby leaves, and often, the entire twig beyond the site of infection die. Almost complete crop loss can be experienced on susceptible cultivars when rain persists during bloom (16). Damage is often experienced several years after a severe infection because of the loss of fruiting spurs.

Controls

Chemicals

Control of brown rot depends on protecting blossoms from infection from popcorn stage through bloom (5).

- **Benomyl -** 50 day PHI. Excellent brown rot material. Labeled for 0.5-0.75 lb. a.i. per acre. Applied during bloom by ground or air to 20% of the acreage at an average rate of 0.5 lb. a.i. per acre (1). Strains of brown rot fungi have been found to be resistant in some California orchards (5). Material is good to excellent on leaf blight (when combined with Captan) jacket rot, and scab (17). Resistant strains of *Botrytis cinera*, have been reported in California on crops other than almond and stone fruits. Resistant strains *Cladosporium carpophilum,* have been reported on other crops but not in California. Not effective for shot hole management and Anthracnose pathogen is mostly insensitive to benomyl (12).

- **Iprodione -** (5 weeks after petal fall). Good brown rot material, excellent when combined with oil (1-2% summer oil), however, water quality can seriously effect performance (17). Labeled for 0.5 lb. a.i. per acre. Applied during bloom by ground or air to 55% of the acreage at an average rate of 0.5 lb. a.i. per acre. Also controls jacket rot and is moderately effective on shot hole.

- **Thiophanate-Methyl** - (cannot be applied after petal fall). Excellent for brown rot, jacket rot and leaf blight when combined with Captan (17). Labeled for 0.75-1.5 lb. a.i. per acre. Applied during bloom by ground or air to 8.8% of the acreage at an average rate of 0.7 lb. a.i. per acre (1). Organisms resistant to benomyl are also probably resistant to this material. Not effective for shot hole management. Anthracnose pathogen is mostly insensitive to thiophanate-methyl (17).

- **Myclobutanil -** 90 days PHI. Good control of brown rot and leaf blight. Some activity on anthracnose when combined with Captan (17). Labeled for 0.15-0.2 lb. a.i. per acre. No record of use in 1995.

Green Fruit Rot or Jacket Rot, *Monilinia spp.* or *Botrytis cinerea* or *Sclerotinia sclerotiorum*:
Green fruit or jacket rot can be caused by any of the above organisms. Spores of *M. laxa* or *M. fructicola* are produced on blighted blossoms or twig cankers, whereas spores of *B. cinerea* are produced on dead or dying tissues of a number of plants including almond and weed species common in almond orchards. Fruiting bodies are produced by *S. sclerotiorum* from soil borne, resistant overwintering structures known as sclerotia. The fruiting bodies then produce spores called ascospores that are forcibly discharged and wind disseminated to senescing blossom tissues. Once a flower is fertilized and the ovary enlarges, the floral tube (jacket) splits and separates from the peduncle. If wet weather persists, the jacket may remain attached to the fruitlet and become colonized by these fungi. The fungi then grow into the immature fruit causing green fruit rot (11). Green fruit rot varies greatly from year to year but can cause up to 10% damage when wet weather persists (16).

Controls

This disease is usually controlled by applications for other bloom time fungal diseases.

- **Captan -** 30 days PHI. Often combined with other materials for resistance management. Provides good control of leaf blight, shothole and scab. Moderately effective on brown rot, jacket rot, and anthracnose (17).
- **Benomyl -** (see brown rot).
- **Iprodione** - (see brown rot).
- **Thiophanate-Methyl** - (see brown rot).

Anthracnose,*Colletotrichum acutatum*:
This disease was not considered a problem in California until the early 1990s. The fungus is now found in all major almond growing regions from Butte County to Kern County and is considered a major threat to the industry in the state. Spores of the fungus are produced on all infected tissues during wet conditions and are disseminated by splashing water. Development of anthracnose is favored by extended, warm, rainy weather. All cultivars appear to be susceptible to anthracnose but there are differences in susceptibility (12).

The fungus overwinters in dead wood or in mummified fruit that remain attached to the tree. Blossoms, leaves, and fruit can be infected. Infected blossoms become blighted, similar to brown rot blossom blight but with orangish spore droplets on the floral cup. Leaf infections are yellow irregular lesions that begin at the leaf margin or tip and advance toward the middle of the leaf. In fruit, infections, symptoms include orangish, circular, sunken lesions in the hull of young fruit. Symptoms are generally observed 2-3 weeks after petal fall as shriveled fruit that become light rusty orange and appear like almond Ablanks.@ In older fruit, symptoms are similar, but profuse gumming often occurs around the infection that continues to develop, destroying the endosperm and killing the embryo. Diseased fruit eventually die, become mummified, and remain attached to the tree where the fungus continues to grow into the almond spur or fruiting branch tissue. The result of this advanced state of host colonization is branch dieback. Nuts remain susceptible throughout the season and when conditions are favorable (rain) can become infected at any time during the season (12). This is an extremely serious disease that requires multiple applications of suitable materials for control. Up to 7 applications in research plots have failed to provide complete control of this disease (13). An increase in the fungicide treatments for management of this disease could lead to serious resistance problems in almonds.

Controls

Chemical

Fungicide treatment is currently the most effective control strategy for managing this disease. In orchards that have a history of anthracnose University of California Guidelines suggest applying fungicide sprays beginning at pink bud and repeat every 10 to 14 days if rains persist (5). Treatment is recommended as long as rains persist. Dormant mummy removal and pruning out dead wood reduces inoculum and severity of disease. Low-angle irrigation that reduces canopy wetness also reduces severity of disease (12).

- **Tebuconazole -** 45 days PHI. Not registered. Proposed labeled rate is 4-8 fl. oz. per acre. In experimental trials, very effective against anthracnose. Excellent on brown rot. Moderately effective on leaf blight. Also shown to be very effective on peach rust. Not effective for shot hole or scab (17).

- **Propiconazole -** 90 days PHI. No use data available. Labeled rate 2-4 fl. oz. per acre.. Most effective material currently registered on anthracnose. Excellent on brown rot. Moderately effective on leaf blight. Also shown to be good against peach rust. Not effective for shot hole or scab (17).

- **Chlorothalonil -** Not registered. (Restricted to bloom and petal fall). Labeled rate 3.0 lb. a.i. per acre. In experimental trials, effective as a protective treatment against anthracnose. Also effective as a protective treatment in experimental trials against brown rot and shot hole (17).

- **Captan -** Control of anthracnose is moderate and variable. Important resistance management tool when used in combination with other materials (11).

- **Myclobutanil -** (Restricted to bloom). Moderately effective on anthracnose. (see brown rot).

Other materials having activity against anthracnose:

- **Azoxystrobin -** Proposed label rate is 12-16 fl oz per acre. Very effective against anthracnose, scab, and Alternaria leaf spot, moderately effective against shothole and brown rot blossom blight. Also shown to be effective against peach rust (17).

- **Trifloxystrobin -** Proposed label rate is 1.5-3 fl. oz. per acre. Very effective against anthracnose. Other diseases not evaluated, (17).

Shot Hole, *Wilsonomyces carpophilus*:
Shot hole attacks both leaves and young fruit and can result in defoliation or premature nut drop. Infection of young fruit can cause fruit drop but infections on older fruit do not develop deep into the hull. Shot hole survives on infected twigs and as spores in healthy buds. Spores are moved by water to new sites; prolonged periods of wetness, either due to rain or sprinkler irrigation are required for the disease to develop. Shot hole can cause losses in yield, defoliation, and weakened trees (11). Almost complete defoliation can occur when rain persists throughout the spring, resulting in a reduction in photosynthesis and weakening of the trees.

Control

Chemical
Contact fungicides serve as protectants, not eradicants, and provide control only if they are applied so foliage and fruit are completely covered before a wet period (6).

- **Captan -** (see brown rot). Provides good control of shot hole.
- **Iprodione -** (see brown rot). Control of shot hole is good but variable (water quality can seriously effect performance).
- **Ziram -** Cannot apply later than 5 weeks after petal fall. An excellent shot-hole material. Provides good control of scab and leaf blight but is weakly effective on brown rot (11). Applied by ground or air to 46% of the acreage at an average rate of 5.6 lb. a.i. per acre (1).
- **Maneb -** 145 days PHI. Labeled for 1.5 qt. per acre. An effective shot-hole material and provides good control of scab. Weakly effective against brown rot (17).
- **Azoxystrobin -** (see anthracnose).

Scab, *Cladosporium carpophilum*:
This disease severely affects cultivars Carmel, NePlus Ultra, Butte, and Peerless, whereas Nonpareil is less susceptible. This organism overwinters as mycelium in twig lesions on almonds and sporulates on these lesions beginning in late March. Spores are wind disseminated and infect leaves, fruit and new shoots during the spring and summer. Hull symptoms develop in late spring and summer and do not result in crop loss during the current year. However, infected leaves drop and can reduce photosynthesis which may eventually weaken the tree, impact fruit bud production and ultimately reduce yield (11).

Control

Treatments must be applied before scab symptoms appear, which can be anytime from late spring through fall. Effective timing of fungicides include petal fall and early spring applications (17). Later applications when used alone are less effective.

- Sulfur (several labels as Wettable Sulfur, Micronized Sulfur, Liquid Lime Sulfur, etc.). Applied during dormant (liquid lime sulfur) and growing season (liquid lime and wettable sulfur). Labeled rates vary but typical rates call for 20 lb. per acre for wettable sulfur and 8-16 gal. per acre of liquid lime sulfur. Moderately effective against scab and rust (17).

- **Captan -** (See shot hole).

- **Ziram -** (See shot hole).

- **Maneb -** (See shot hole).

- **Azoxystrobin -** (See anthracnose).

Leaf Blight, *Seimatosporium lichenicola*:
Leaf blight results in sudden death of leaves in almonds. In spring and throughout the summer, infected leaves wither, turn brown and die. Buds in axils of infected leaves die in the fall following current season infections and the petioles remain on the tree until the following spring. Dark, fruiting bodies of the fungus develop on petioles in the winter (11). Spores are spread by rain and leaf blight is favored by wet spring weather. Leaf blight is usually not severe or widespread; it rarely destroys more than 20% of the leaves in one season. However repeated early death of leaves will weaken trees, and loss of spur development due to death of buds in the leaf axils will contribute to yield loss (5).

Control

Chemical

- **Captan -** (see brown rot). One of the better materials for leaf blight (17).

- **Ziram -** (see shot hole). Control is moderate and variable (17).

Alternaria Leaf Spot,*Alternaria alternata*:
Alternaria develops in late spring and through summer. In orchards with poor ventilation, high humidity, and prolonged periods of leaf wetness, trees commonly defoliate from severe Alternaria leaf spot infections (11).

Control

Cultural
Pruning to open the canopy, planting design and spacing to improve air-circulation and to reduce humidity will help manage this disease (11).

Chemical

- **Azoxystrobin -** (see anthracnose). . Section 18 registration in all counties in the Sacramento Valley and San Joaquin Valley. Labeled rate is 12-16 fl. oz. per acre.

Leaf Rust,*Tranzschelia discolor*:
Rust typically develops in summer and fall in almonds. Angular yellow leaf spots on the upper leaf surface and rusty brown masses of spores on the lower leaf surface help distinguish this disease. Leaf rust can cause severe defoliation in a short period of time if conditions are favorable. Almond fruit are not infected. This fungus has a complex life cycle and has been reported from alternate hosts. Twig cankers have also been found on almond similar to peach and these are probably the main mechanism of survival during almond dormancy (11).

Controls

- **Maneb** -145 days PHI. The most effective material for this disease. Also provides good control of scab and is somewhat effective on shothole, brown rot and leaf blight (12).
- **Iprodione -** (see brown rot). Moderately effective for control of rust (17).
- **Sulfur - (see eriophyid mites and scab). Moderately effective for rust control (17).**
- **Azoxystrobin - (see anthracnose).**
- **Propiconazole - (see anthracnose).**

- **Tebuconazole - (see anthracnose).**

Bacterial Canker and Blast, *Pseudomonas syringae*:
Pseudomonas syringae is expressed in almonds as either a canker or on buds and leaves. Bacterial canker afflicts all commercial *Prunus* species. The causal bacterium is a pathogen of at least 80 different plant species and a common inhabitant of plant surfaces. The disease invades the scaffolds and trunks of trees and can devastate young trees, whereas trees 6 to 8 years old are somewhat resistant. This disease is more severe on trees grown in sandy rather than heavy soils. Bacterial canker causes isolated cankers on or death of most or all the above ground parts of almond trees. Diseased trees have a strong vinegar odor, hence the terms sour sap and souring out. The disease is active in winter and a young tree infected by bacterial canker usually dies before budbreak in the spring. Blast, caused by the same organism, may affect dormant or opening buds, flowers, and leaves. Infected buds fail to open and later dry and shrivel. A small canker is often found at the base of the dead bud. Blossoms turn dark brown then black and remain attached to the tree. Blast causes brownish-black spots of varying size and shape on leaves. Entire spurs and young green shoots may be killed, but the bacteria do not usually move very far into older twigs (6).

Control

Pre-plant fumigation plus frequent irrigation and post-plant nematicides each fall for the first eight years of orchard life are the only control measures. This is expensive and there is only one post-plant nematicide available.

Cultural

Measures that encourage healthy plant growth also protect against bacterial canker. Avoid factors that may pre-dispose trees to disease such as poor nutrition, cold temperatures, and other stresses. Large populations of ring nematode are associated with bacterial canker sites. Soil fumigation that depresses ring nematode populations before trees are planted reduces the incidence and severity of bacterial canker (6). (see Nematodes).

Research has not discovered a reliable control for bacterial blast. Some experiments with copper sprays applied before and during early bloom have shown promise, but positive results are not easily confirmed (5). Copper resistant bacteria have been confirmed in orchards where growers routinely used copper sprays to try to reduce the severity of bacterial blast.

Armillaria Root Rot, *Armillaria mellea*:
The severity of this fungus disease depends on the rootstock and the strain of *A. mellea*. The pathogen invades the roots, crown, and basal trunk, eventually girdling the crown region and destroying the entire root system causing death of the tree. Symptoms of the disease are creamy white, fan-shaped plaques of fungal mycelia beneath the bark and black strands called rhizomorphs on the surface of infected roots. After rains in the fall or spring, a cluster of mushrooms often appears at the base of infected trees. The fungus develops most rapidly in moist cool soil. It can survive for many years in dead roots of many different species of trees (6). Generally, clusters of trees may be infected at one or several sites in the orchard (2). A localized problem but can cause 25% yield loss in infected orchards.

Controls

Cultural Control
Oak root fungus survives on infected roots. It is not practical to remove old roots in replant situations. Marianna 2624 rootstock is somewhat resistant but many cultivars are not compatible with the rootstock (6).

Chemical

- Methyl Bromide has shown some promise for control of *A. mellea* at the rate of 300-600 lb. per acre applied by injection with tarping. This works well in settings where there is only six feet or less of root system depth and soil has been dried properly. It is recommended that a deep rooted cover crop be grown on the soil to dry it out completely before treating. Even under these conditions, eradication is hardly ever achieved and this material is very seldom applied solely for this purpose (6) (see nematodes).

- **Sodium tetrathiocarbamate** B 14 days PHI. Labeled rate is 2400 ppm a.i. as a pre-plant treatment and 1450 ppm a.i. as a post-plant treatment. Recently registered as a soil fumigant on almonds and peaches. Initial research indicates that pre- and post-plant applications are required to be equivalent to methyl bromide for reducing inoculum (e.g., infested roots) (17). Others feel that it is not effective as a pre-plant treatment. (McKenry, personal communication)

Crown Gall, *Agrobacterium tumefaciens*:
Although crown gall can affect established orchards, the disease is most damaging to young trees. If left unchecked, crown gall may progress around the crown weakening and eventually girdling the tree. Young galls are smooth; as they age, they become rough and increase in size. Old galls are dark, brittle

and cracked. The pathogen can only infect through wounds and young trees in nurseries are particularly prone to infection because of the many potential injuries during rearing and digging (2). If left uncontrolled, losses of 10% can occur. Dead gall tissue can predispose trees to infection by wood decay fungi.

Controls

Crown gall bacteria enter the tree through wounds only. The best prevention for the disease is prevention of injury to trees during planting and cultural practices. Purchase young trees from a reputable nursery, plant them with a minimum of handling, and avoid root injuries (6).

Biological
Agrobacterium radiobacter-84 is a biological control agent used as a root spray or dip before planting in the field on 85% of nursery trees (6).

Chemical

- **Gallex** J is used to selectively kill tumors on individual trees in existing orchards. The treatment is most effective when use on trees 4 years old or less. This procedure is expensive and difficult to carry out (5).

Root and Crown Rot,*Phytophthora* spp.:
About 14 different *Phytophthora* species attack almond trees. All *Phytophthora* species are soil-inhabiting fungi, although not all are present in all orchards afflicted by crown and root rot. Canal and river water is frequently contaminated with *Phytophthora* and the pathogens are brought into orchards and fields in irrigation water drawn from these sources. The pathogen enters the tree either at the crown near the soil line, at the major roots or at the feeder roots, depending on the species. Trees affected with *Phytophthora* first show small leaves, sparse foliage, and lack of terminal growth. Infected trees may decline for several years or die within the same growing season in which the foliage symptoms first appear. *Phytophthora* can survive in the soil for many years and spreads and infects the trees during moist cool weather in spring and fall (2). A localized problem affecting 20% of the orchards. Yield losses of 50% can occur in infected orchards.

Controls

Cultural
Rootstocks vary in susceptibility to the different *Phytophthora* species; none are resistant to all species. The success of a rootstock may depend in part upon the species of *Phytophthora* present in the orchard.

In general, plum rootstocks are more resistant than are peach or apricot. Of the plum rootstocks, Marianna 2624 is the most tolerant and is the only plum rootstock available for almonds. Careful soil moisture management is the key to managing *Phytophthora*. Plant on soil with good surface and internal drainage. Plant on ridges to keep standing water from around the base of the trees (2).

Chemical

- **Mefenoxam -** Labeled rate is 2 qt. per acre. Do not apply more than 3 applications per year (17). Applied to the soil as a drench on 1% of the acreage (1).

- **Metalaxyl -** Labeled rate is 2 gal. per acre. Do not apply more than 3 applications per year (17). Applied to soil as drench to 1.2% of the acreage at an average rate of 0.19 lb. a.i. per acre. (<10% of soil surface is usually treated).

- **Fosetyl-al** - Non-bearing trees only. Labeled rate 3-5 lb. Per 100 gal. applied up to four times per season (17). Applied foliar to 0.08% of the acreage at the rate of 1.0 lb. a.i. per acre.

Ceratocystis Canker, *Ceratocystis fimbriata*:
The causal fungus also attacks other stone fruits but is frequently associated with almonds because infection sites are commonly injuries to the bark caused by mallets used to knock branches, or improperly adjusted mechanical shakers. This fungus is transmitted by insects attracted to wounds. Once deposited in open wounds, spores germinate and initiate new infections. The resulting cankers expand slowly and may continue to grow for several years. Eventually, large cankers weaken diseased limbs and trunks and may lead to collapse of scaffolds or trees. Rain may also wash spores into pruning wounds (6).

Controls

The best control is prevention of bark injuries. Properly adjusted shakers and careful operators are essential to prevent bark injury. Bark of recently watered trees is more susceptible to shaker damage so it is best to wait as long as possible after irrigating before shaking trees (6).

Verticillium wilt, *Verticillium dahliae*:
Verticillium dahliae is a soil-inhabiting fungus found in nearly all soils in the temperate regions of the

world. It is capable of parasitizing hundreds of plant species and often becomes a serious problem where suitable host plants are grown. The fungus enters through young roots and becomes established in the xylem tissue causing it to become nonfunctional. *Verticillium* wilt only attacks young almond trees less than 5 years old. Leaves on infected branches die quickly, becoming a light tan color and often remain attached to the plant. The vascular tissue darkens and extends down the infected scaffold into the trunk and root system. Typically, one scaffold or one side of the tree dies but the disease usually does not kill entire trees. Affected scaffolds will often resprout and releaf later in the growing season (6).

Controls

The only control for *Verticillium* wilt is prevention. Selection of an orchard site where cotton, tomato, melons, potato or other highly susceptible crops have never grown is important to prevent this disease (6).

Wood Decay, Numerous species of fungi in the *Basidiomycota*, *Aphyllophorales*:
Fungi that cause this disease produce air-borne spores that infect exposed wood that result from injuries that commonly result from improper pruning, farming equipment (cultivators, mowers, improperly adjusted mechanical shakers, etc.), or wounds that result from other biological agents (e.g., crown gall). These fungi enter the xylem tissue where they cause white or brown rots that substantially weaken the support strength of the wood. Symptoms of decayed wood are bleached white, soft to punky wood (white rot) or brown, cracked, and friable wood (brown rot). Scaffold branch breakage and tree fallings that have been attributed to environmental damage (e.g., wind or storm damage) or to crop weight are commonly the result of predisposition from wood decay fungi (17).

Controls

The best control is prevention of tree injuries. Careful mowing and cultivation near trunks and exposed roots and properly adjusted mechanical harvesting equipment and careful operators are essential to prevent tree injury. Proper pruning to prevent flush and stub cuts is also essential. Irrigation guards that prevent trunk wetting from irrigation sprinklers may also be beneficial. Pruning wound paints (e.g., tar tree paints, copper-based mixes, etc.) have been used but their long-term benefits have been questioned (17).

Nemataodes

Lesion Nematode, *Pratylenchus vulnus*
Ring Nematode, *Criconemella xenoplax*
Root Knot Nematode, *Meloidogyne spp.*
Plant parasitic nematodes are microscopic roundworms that feed on plant roots of most plants including almonds. They live in soil or within the cortical tissues of the roots. The extent of the damage caused by nematodes in almonds depends largely on the density of the nematode population, soil conditions and rootstock selection. In situations where tree growth has been visibly impaired by the second year, the affected trees may never overcome the nematode problem. Symptoms of a nematode infestation include lack of vigor, small leaves, dieback of twigs and a sparse root system, particularly the lack of small feeder roots. Root galls are an indication of root knot nematode.

Ring nematodes spend their lives in soil feeding on roots. Feeding by ring nematodes stresses trees and makes them more susceptible to bacterial canker (*Pseudomonas syringae*). Ring nematode is common in sandier soils of the northern San Joaquin Valley, but also along fans of old river tributaries further south.

Dagger nematodes are most common in northern California soils. They also occur frequently in other production areas but scientists do not expect this species to cause tree damage unless a damaging ringspot virus is also present or the population is large, more than 400 per pint of soil (6).

Root lesion nematodes damage roots by moving through cortical tissues and feeding in these areas. Among first-leaf trees, damage due to the replant problems and the lesion nematode can be severe. Stunted trees occur within irregular, circular-shaped areas across the orchard. Among older plantings damage is barely discernible. Fruit size and quantity are reduced with only slight apparent stunting in overall tree growth. Yield and size data of plum on both peach and plum rootstocks indicate up to a l6% reduction in marketable fruit, with peach rootstocks being more adversely affected than plum. Similar rootstocks are used in almonds and similar reductions in yield would be expected.

Root knot nematodes take up a single feeding site within a root where they remain for their entire life. Some legumes grown for cover crop on the orchard floor provide an excellent habitat and food source for root knot nematode. Unfortunately many cover crops, including clovers do not show obvious symptoms of root galling. Nemaguard rootstock is resistant to root knot nematode and widely planted particularly in the San Joaquin valley (6).

Viruses are not a problem with certified virus-free *Prunus* rootstocks. If nurseries ever begin producing stock from nematode infested sites because a suitable fumigant is unavailable, viruses will become a significant problem.

Controls

Cultural
Management of nematodes starts before planting an almond orchard. Soil samples should be taken to identify the nematode species present to determine a course of action (6).

Continued fallowing for at least 4 years or use of non-host crop rotation can significantly reduce nematode populations before planting. However, this is not an economically feasible option (3).

To prevent the introduction of nematodes in an orchard, certified nematode free planting stock is used.

Rootstock selection is also important because rootstocks for almonds differ in response to various parasitic nematodes. None of the more commonly used rootstocks are resistant to all the plant-parasitic nematodes. However Nemaguard peach, the most common almond rootstock, is resistant to all the common root knot nematode species found in California. The plum rootstock Marianna 2624 is also resistant to root knot nematodes but has limited utility because of soil and incompatibility problems (3).

Biological
There are no known biological agents that are deliverable to soil or the surfaces of roots that will provide relief from nematodes (3).

Chemical

- Post-plant Treatments
  There is one California-registered post-plant nematicide for bearing almonds. Enzone has effectiveness against the ectoparasitic ring nematode (3).

- Pre-plant Treatments
  Pre-plant fumigation is common in replant situations. Nematode numbers are greatly reduced for as long as 6 years by fallowing 1 or 2 years and then fumigating prior to replanting. The fumigation serves the important function of killing all the remaining roots within the surface 5 feet of soil profile. Without fumigation these roots remain alive two years after the old trees have been removed and the soil deep-ripped. Few growers could afford to idle their land for the 4 to 5 years necessary to achieve adequate relief from the replant problem plus root lesion nematode (3).

  - **Methyl Bromide** is used as a pre-plant treatment when replanting into soils previously in orchard crops. It is applied one to two feet deep, usually with a plastic tarpaulin stretched over the field surface. In order to save on costs, growers in some regions may treat only the planting strips or the individual planting sites at approximately 100 lb. per acre, with or without use of a tarp. There are no effective post-plant nematicides and no rootstocks are known to be resistant to root lesion nematode so growers make a critical decision whenever they decide on a partial fumigation or to not fumigate at all. The damage by nematodes is severe enough on almond that without methyl bromide or an effective alternative, the resulting orchards will be weaker with fewer roots and any damage with above ground pests will be increased. Fumigation is common in replant situations in the San Joaquin Valley. Additionally, availability of an effective pre-plant material has greatly reduced the need for annual post-plant treatments.

- **1,3 Dichloropropene** is the closest replacement for methyl bromide, but its use for this purpose in California was suspended from 1990 to 1996 and today there are serious acreage restrictions and a limitation of 350 lb. per acre associated with its use. Use data are not available at this time. Excessive volatilization has been the key shortcoming to its recent use and the tree fruit industry has been searching for improved methods of application to limit in-field volatilization without jeopardizing efficacy. Prior to 1990, the normal treatment rates for 1,3 Dichloropropene were up to 800 lb. per acre. Newer methods of killing roots plus the lowered rates of 1,3 Dichloropropene and the use of a water seal containing metam-sodium biocide will soon receive field evaluation as a methyl bromide alternative. It is premature to predict the results in commercial settings (3).

- **Metam-Sodium** B Applied at individual tree sites pre-plant to <0.01% of the acreage at an average rate of 60 lb. a.i. per acre. This material is difficult to move deep enough into the soil to be of much use (3).

- **Fenamiphos** B For non-bearing trees only. Applied to soil to 0.02% of the acreage at an average rate of 7.26 lb. a.i. per acre. Efficacy is variable. No California registration is expected for bearing trees.

- **Sodium Tetrathiocarbonate** B This material releases carbon disulfide when in contact with soil. Several small-scale field trials have shown that flood applications of this material can reduce ring nematode populations on almonds, thereby reducing the incidence of bacterial canker (3).

Weeds

In addition to problems at harvest, weeds can cause a multitude of other problems in almond orchards by reducing the growth of young trees because they compete for water, nutrients, and space. Weeds also increase water use, cause vertebrate and invertebrate and other pest problems, and may enhance the potential for disease such as crown rot. Most orchards are no-till requiring the use of herbicides and/or mowing to control weeds. The increasing use of more efficient low-volume irrigation systems has increased the need for selective pre-emergence herbicide use in drip, microsprinkler, and sprinkler-irrigated orchards. Pre-emergent herbicides are generally used only in the tree row. This reduces the total amount of herbicides and prevents the surface roots in the tree row from being damaged by cultivation equipment. By treating the tree row only, 25% to 33% of the total acreage is treated. Pre-emergence and post-emergence, or combinations of pre- and post-emergent herbicides are often used between tree rows. Soil characteristics have an effect on the weed spectrum (often 15-30 species per orchard), the number of cultivations and irrigations required, and the residual activity of herbicides. Irrigation methods and the amount of irrigation or rainfall affects herbicide selection and the residual control achieved.

Almond orchards may benefit from plants on the orchard floor if they are carefully managed. These plants in a well-maintained ground cover, can help increase water infiltration, reduce soil compaction, maintain soil organic matter content, cool the orchard, and provide habitat for beneficial insects (5).
Monitoring: Treatment decisions and herbicide selections are based on dormant and early summer weed surveys.

Controls

Chemical

- **Glyphosate -** 3 days PHI. Most often used herbicide (16). Applied during the dormant, pre- and/or post-bloom by ground. Often applied at low rates several times during the season. This accounts for the fact that use data indicate this material is applied to >100% of the acreage. Annual use rate averages 0.75 lb. a.i. per acre (1). Nonselective systemic used for a broad range of weed species. Effective anytime on emerged, irrigated, rapidly growing, non-stressed weeds, but activity is slower in lower temperatures. Best material available for most perennial weeds. Cannot eradicate field bindweed or nutsedge. Not effective on some broadleaf weeds at older stages of growth (malva and filaree). Continued use of this material leads to a shift of species and selection of tolerant species (16). Light activated spray technology has reduced the amount of material applied when weed cover is low by 50 to 80%.

- **Oxyfluorfen -** Apply following harvest up to February 15. Applied by ground one time per season on 41% of acreage at an average rate of 0.2 lb. a.i. per acre (1). Selective broadleaf herbicide effective as a pre- and post-emergent material. Particularly useful when combined with glyphosate to increase efficacy on various broadleaf weed species and to prevent broadleaf species shifts with glyphosate. Oxyfluorfen is the only effective material for malva (16).

- **Simazine -** 21 days PHI. Applied anytime to bare soil or in combination with glyphosate by ground one time per season on 14.2% of the acreage at an average rate of 0.61 lb. a.i. per acre (1). Pre-emergence herbicide of most annual grasses and many broadleaf weeds. Effective when combined with translocated herbicide such as glyphosate or the contact herbicide paraquat, and a broadleaf pre-emergence herbicide as in oxyfluorfen. Typically used for down the row treatment to maintain clean row for irrigation emitters and season long weed suppression (5). Simazine is the only material effective on fleabane and horseweed. Weak in controlling grasses (16).

- **Paraquat -** 0 days PHI. Applied by ground one or more times per season to 30% of the acreage at an average rate of 0.73 lb. a.i. per acre (1). Nonselective post-emergence material used for quick burn-down of most weed species. Less effective against perennials that will regrow with vigor, e.g., bermudagrass, dallisgrass, johnsongrass, and bindweed (16). Most effective when used on early spring or winter growth of annual grass species in combination with pre-emergence herbicides.

- **2-4-D -** 60 days PHI. Applied as a directed spray post-bloom by ground one or two times to 17.5% of the acreage at the average rate of 1.78 lb. a.i. per acre (1). Post-emergence systemic herbicide selective for most broadleaf annual weeds. Provides partial control of field bindweed. Useful for controlling troublesome perennials (16).

- **Oryzalin -** 0 days PHI. Applied at 2-4 lb. as pre-emergence in the tree strip by ground one time per season on 17.5% of the acreage at the average per acre rate of 1.8 lb. a.i. per season (1). Pre-emergence selective herbicide most effective on annual grass species and numerous broadleaf annuals. Very safe for young or newly planted trees and on sandy or sandy loam soils (16). It is used to maintain control in strips down the row. Often used in combination with other pre-emergence herbicides.

- **Norflurazon -** 60 days PHI. Applied pre-bloom by ground one time per season on 9% of the acreage at the rate of 1.06 lb. a.i. per acre (1). Pre-emergence selective herbicide similar to oryzalin, but is effective on more annual broadleaf and grass species. Can suppress yellow nutsedge or bermudagrass when used year after year (16). Can cause minor damage to younger trees or those planted on sandy or sandy loam soils. Usually used on new plantings. Primarily a grass control material (16).

- **Trifluralin -** 0 days PHI. Applied pre-bloom by ground one time per season on 1.25% of the acreage at the rate of 1.27 lb. a.i. per acre (1). Pre-emergence selective herbicide for annual grasses. It must be combined with broadleaf herbicides and incorporated promptly for best results. Used on new plantings or established orchards as a strip treatment. Suppresses bermuda, johnson and dallis grass rhizomes (16).

- **Napropamide -** 0 days PHI. Applied pre-bloom one time per season on 2% of the acreage at the rate of 4 lb. a.i. per season in the tree row (1). Pre-emergence herbicide effective on annual grasses and several annual broadleaves (16). Must be applied and incorporated with irrigation or rain within seven days. Very effective in maintaining weed free strips down the row. May be applied in late winter with glyphosate for late burn down. Used on bearing and non-bearing trees.

- **Pendimethalin -** Non-bearing trees only. Applied pre-emergence by ground one time per season to 1.8% of the acreage at the rate of 2.0 lb. a.i. per acre. Effective on annual grasses and some broadleaf weeds (16).

Vertebrate Pests

Ground Squirrels, *Spermophilus beecheyi*:
California ground squirrels are medium-sized rodents up to 20 inches long measured from the head to the tip of the tail. Ground squirrels are responsible for significant damage in almond orchards throughout the state. California ground squirrels live in underground burrows where they form colonies of 2 to 20 or more animals. They adapt well to human activities and are found along road or ditch banks, fence rows and within or bordering many agricultural crops. They are primarily herbivorous. During early spring they consume a variety of green grasses and other herbaceous plants. When these begin to dry and form seeds, the squirrels switch to seeds, grains, and nuts.

Ground squirrels often infest almond orchards. They easily climb trees and feed on nuts from set to maturity and through harvest. Adult squirrels often cache seeds and nuts in their burrows, especially in the late summer and early fall. During this period almond losses greatly exceed the number the squirrels have actually consumed.

Squirrels dig extensive burrow systems, bringing soil and rocks to the surface creating mounds, which may cause damage to orchard equipment. The burrows and mounds create problems for harvesting operations, as nuts are shaken off the tree and swept off the ground.

Control

Habitat modification by removing piles of orchard prunings and other harborage offers little relief, although, this does make monitoring of squirrel activity easier.

Trapping is impractical and time-consuming, except with small populations.

Chemical
Fumigation with gas cartridges can be effective in spring and early summer when soil moisture is high enough to retain the concentrations of toxic gases. It is ineffective in summer, particularly when the adult squirrels are estivating (summer hibernation) because the adult squirrels create a soil plug to seal themselves in the nest chamber.

- **Strychnine** B 0.5% baits. Must be used in bait boxes. Strychnine is highly toxic to non-target mammals and birds.

- **Brodifacoum** B 0.01% baits. No use data available as this is a fairly new use. A single feeding of this anticoagulant will kill squirrels.

- **Chlorophacinone** B 0.005% and 0.01% baits used. Requires multiple feedings for 6 days or more. Used in bait boxes, or rarely broadcast (if label allows).

- **Diphacinone** B 0.005% and 0.01% baits used. Requires multiple feedings for 6 days or more. Used in bait boxes, or rarely broadcast (if label allows).

Pocket Gophers, *Thomomys spp*:
Pocket gophers are stout-bodied, short-legged rodents 6 to 8 inches long. Pocket gophers are common in areas of abundant plant growth. They feed primarily on succulent underground parts of herbaceous plants. They live almost entirely underground. They create extensive burrows for living and feeding.

Pocket gophers frequently live in orchards. They are active throughout the year. In ideal situations, their numbers may reach 30 to 40 gophers per acre. They cause tree damage or death by girdling roots or crowns at or below the soil level.

Control

Habitat modification to remove vegetation will discourage gophers.

No chemical or mechanical repellents are effective in controlling pocket gophers.

Trapping B Traps placed in the burrows are effective for small populations. Trapping is time consuming and expensive.

Chemical

- **Strychnine** B 0.5% bait. Placed in the burrow by use of mechanical burrow builder or with hand probes. Usually very effective with virtually no secondary wildlife hazards.

- **Chlorphacinone** and **Diphacinone** B 0.005% and 0.01% baits. Applied to burrows in the same manner as strychnine.

- **Aluminum phosphide** B The only fumigant that has shown some degree of effectiveness. Time consuming to hand treat burrows with pellets and seal hole. Requires repeat treatments for effective control.

Post Harvest

Dried almonds are fumigated after harvest with phosphine gas primarily for control of navel orangeworm, peach twig borer, ants and storage pests. Navel orangeworm damage is directly linked to the presence of aflatoxins in almonds. Control of these insects is critical to maintain markets that demand insect-free almonds. Many countries require fumigation prior to export to control pests that could be present and to prevent infestations in route. The only alternative to phosphine is methyl bromide. All incoming almonds are fumigated with phosphine at label rates by the processor when they are received and usually again prior to shipping.

U.S.D.A.-ARS scientists at Fresno are currently investigating controlled atmosphere technology and the use of several possible candidate compounds (carbonyl sulfide, sulfuryl fluoride, and methyl iodide) as replacements for at least some of the current methyl bromide uses. These tests have just begun so it is too early to judge their potential usefulness for almonds. None of the chemicals under test are registered for use. The use of controlled atmosphere is very slow (e.g., 5 to 7 days or more) and would be extremely difficult to accomplish with large volumes of almonds and existing storage facilities.

Current Research

The anticipated loss of methyl bromide has prompted the tree fruit industry in California to search for other methods that result in death of the remnant roots. By cutting off trees at their trunks and painting the cambium region with glyphosate systemic herbicide, it has been possible to completely kill the roots so that 18 months after such a treatment trees can be replanted without experiencing the replant problem (3). At this point in time, none of this work has been conducted on trees older than 15 years and it only provides 1 year of nematode relief, but in concert with other nematode controlling strategies, this methodology may replace some of the need for soil fumigation.

Work with ozone as a soil fumigant is also ongoing on prunes. Preliminary data indicate the product moves at nematicidal concentrations for 6-12 inches from the point of injection. Cost projections based on trials indicate ozone could be applied at a cost comparable to other nematicides.

For nematode control, metabolites produced by myrothecium fungus were recently registered as a nematicide under the brand name DiTera J . Performance of this product is highly variable in small plots and there is much about this biologically derived product that is not understood. DiTera J is now receiving commercial evaluation in plots in prunes in the Sacramento Valley.

First year treatments of oxamyl via drip or microsprinklers can give protection against root lesion nematode. No registrations are expected even though there are no residues from this use. This material would be very beneficial for the first year of starting almonds.

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Pest Management Strategic Plans

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Peach	CA
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